

Carbon Sequestration in Community Forests: Trade-offs, Multiple Outcomes and Institutional Diversity in the Bolivian Amazon

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ABSTRACT

Carbon sequestration in community forests presents a major challenge for the Reducing Emissions from Deforestation and Forest Degradation (REDD+) programme. This article uses a comparative analysis of the agricultural and forestry practices of indigenous peoples and settlers in the Bolivian Amazon to show how community-level institutions regulate the trade-offs between community livelihoods, forest species diversity, and carbon sequestration. The authors argue that REDD+ implementation in such areas runs the risk of: 1) reinforcing economic inequalities based on previous and potential land use impacts on ecosystems (baseline), depending on the socio-cultural groups targeted; 2) increasing pressure on land used for food production, possibly reducing food security and redirecting labour towards scarce off-farm income opportunities; 3) increasing dependence on external funding and carbon market fluctuations instead of local production strategies; and 4) further incentivising the privatization and commodification of land to avoid transaction costs associated with collective property rights. The article also advises against taking a strictly economic, market-based approach to carbon sequestration, arguing that such an approach could endanger fragile socio-ecological systems. REDD+ schemes should directly support existing efforts towards forest sustainability rather than simply compensating local land users for avoiding deforestation and forest degradation.

INTRODUCTION

To many scholars and policy makers, REDD+ is more than just a programme for reducing emissions from deforestation and forest degradation.

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REDD+ is seen as a unique worldwide opportunity for obtaining fresh financial and technical support for more sustainable management of forests by local communities (Eliasch, 2008). However, the ways in which REDD+ is generally implemented are increasingly being called into question (McAfee, 2012; McAfee and Shapiro, 2010). One criticism concerns the highly uncertain effects of REDD+ implementation in terms of trade-offs between local livelihoods, biodiversity conservation and carbon sequestration (Corbera and Brown, 2010; Hiraldo and Tanner, 2011). The prevalent focus on reducing emissions from deforestation and forest degradation tends to over-emphasize forests as 'carbon sinks' and overlooks other livelihood-relevant outcomes for local communities, such as non-timber products, agriculture and livestock (Campbell, 2009; Coomes et al., 2008; Putz and Redford, 2009).

Too little attention is given to the multiple functions (e.g. income generation, food security, social security, legal and political legitimacy) that are potentially or effectively fulfilled by community-based resource systems, as well as to how local institutions regulate trade-offs between the related outcomes (Wunder et al., 2008). Carbon sequestration projects that focus on forested areas often overlook local stakeholders' interactions with adjacent pastoral and agricultural areas. In classical REDD+ policy assessments, opportunity cost baselines are defined based on annual returns per hectare derived from regional or national secondary data, which are then compared to carbon market offset prices (Grieg-Gran, 2006). There is very little empirical knowledge about how local stakeholders actually depend on forests and agriculture for their livelihood and how this translates to reliable carbon emission estimates.

Justifiable Scepticism about REDD+ Benefits for Local Community Livelihoods

Evaluations of payment for ecosystem services (PES) projects aimed at compensating local communities for carbon storage in Bolivia and in several other Latin American countries showed that benefits for local stakeholders were generally limited to financial contributions and capacity building (Caplow et al., 2011; Wunder et al., 2008). These assessments also highlighted the difficult economic transitions that communities have to go through in order to make their previous livelihood strategies compatible with the requirements of a carbon sequestration programme. Other problems mentioned include high degrees of leakage¹ and difficulties in ensuring permanence, stakeholder liability, and monitoring of carbon sequestration programmes (Asquith et al., 2002; Hall, 2008; Pagiola, 2008; Peskett et al., 2008; Wunder and Albán, 2008; Wunder et al., 2008). Scholars have stressed that in the absence of economic alternatives to agriculture, flat payment

1. Leakage in this context occurs when interventions to reduce emissions in one area (sub-national or national) lead to an increase in emissions elsewhere.

rates to compensate opportunity costs constitute insufficient incentives for all farmers to accept involvement in a carbon sequestration project. Hypothetical REDD+ compensation based on current market prices would suffice to compensate shifting cultivators, but would not be an attractive monetary incentive to the timber extraction industry, cattle ranchers, and large-scale commercial producers of soya bean, cocoa and oil palm (Börner, 2007; Campbell, 2009). What is more, carbon projects can actually harm particular groups of people under certain circumstances. For small-scale farmers practising shifting cultivation, even a small decrease in their basic crop production may represent a significant drop in income or food security (Mertz, 2009). Systemic effects on the market prices of basic products (i.e. rice or maize) due to reduced overall food supply could also directly affect poor consumers (Grieg-Gran et al., 2005). Such direct and indirect economic effects require specific and careful policy adjustments (Grieg-Gran et al., 2005; Peskett et al., 2008). Finally, a number of studies call for more holistic approaches to carbon sequestration projects that consider the trade-offs between financial PES and multiple land and forest outcomes (Asquith et al., 2002; Karsenti, 2007; Robertson and Wunder, 2005; Van Hecken and Bastianensen, 2010).

Adequate Institutional Arrangements under REDD+

Current debates on carbon sequestration address the question of land rights as a core problem during PES implementation (Cotula and Mayers, 2009; Savaresi and Morgera, 2009; Sunderlin et al., 2009). Adequate property rights that clearly relate to 'carbon producers' are difficult to establish, and new institutional arrangements can pose significant threats to traditional resource systems (Asquith et al., 2002). In tropical rainforest contexts, resource appropriation has been accompanied by flexible institutions that reflect the dynamics of social-ecological systems (Peluso, 1996). A single tree can be owned by different users and at the same time embedded in various spiritual beliefs or other social values. Because tropical forest ecosystems are characterized by high subtractability and low excludability, these systems are better managed collectively than as individual properties (Agrawal, 2007; Bromley and Cernea, 1989). Studies of carbon sequestration in forests often remain evasive when it comes to which categories of land rights are most appropriate for implementing PES. Recent approaches have called for greater participation by indigenous and peasant communities in political decision making (Sikor et al., 2010) and for acceleration of land titling (Morgera, 2009). However, none of these authors assessed which land rights categories and related institutional arrangements are best suited for participatory decision making, for example by evaluating the implications of individual versus collective land property rights for achieving effectiveness in REDD+ projects.

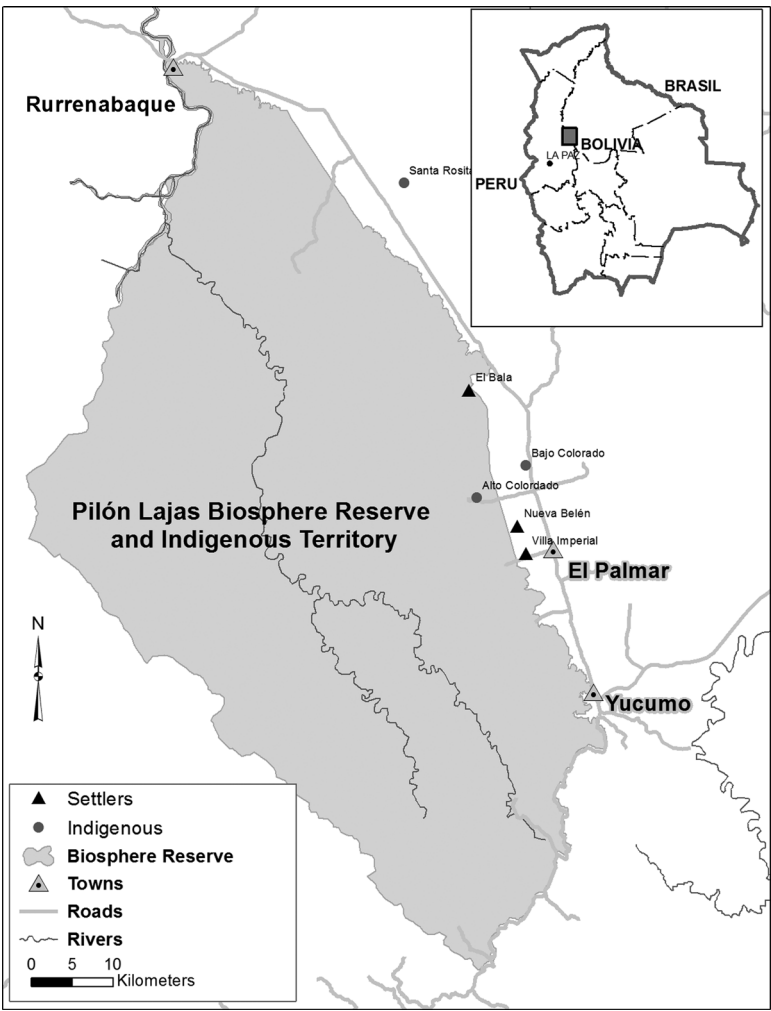
Against this background, we argue that a three-dimensional approach focusing simultaneously on the institutional, socio-economic and biophysical dimensions of the interconnections between human and natural resource systems is needed to better understand what could be the effects of implementing the REDD+ programme in tropical forest areas. The main objective of this article is to compare the current agricultural and forestry practices of two different population groups living in the same area in the Bolivian lowlands — the indigenous Tsimane' and Andean settlers — and to see how these practices are currently influencing trade-offs between multiple forest outcomes. More specifically, our research sought to: 1) analyse trade-offs between multiple productive activities, carbon sequestration, and tree species diversity conservation; 2) understand how indigenous peoples' and settlers' institutional configurations (particularly local governance and land rights) influence those trade-offs; and 3) assess potentials and limitations of REDD+, with a particular focus on specific socio-economic and institutional characteristics.

METHODOLOGY

We conducted our comparative study in the buffer zone of the Pilon Lajas Biosphere Reserve (PLR) in the Beni department of Bolivia, 370 km north of La Paz (Figure 1). The PLR lies on the border between two bio-geographical sub-regions: montane cloud forests (*yungas*) and the Madeira humid forest. Six human settlements were selected according to multiple criteria, such as communities' willingness to be part of the study, similar distance from the main road, similar average population density, and communities' belonging to the ethnic categories of either indigenous Tsimane' or Andean settlers. Considering two ethnic categories allowed a comparison of how different social-ecological systems, represented by three communities of indigenous Tsimane' and three communities of Andean settlers, affect multiple forest outcomes in a similar ecosystem. This selection implies a clear sociological differentiation that is important for understanding how local institutional differences affect potential implementation of a REDD+ mechanism. The Tsimane' have been visiting the area since time immemorial, and were granted a single collective land title for a total of twenty-one communities in the early 1990s (Bottazzi, 2008; 2009). The settlers belong to a first generation of Quechua migrants coming mainly from the Andean city of Potosí. They were granted individual property titles by the government in the course of a 'colonization programme' launched in the 1970s.

Fieldwork took place from February to July 2011. A survey was applied to the entire population of the six selected communities, totalling 128 households, of which sixty-six were Tsimane' households and sixty-two were Andean settlers' households. The criteria for community selection were a similar population size for Tsimane' and Andean settlers, as well as a similar

Figure 1. Study Area: The Pílon Lajas Biosphere Reserve and Indigenous Territory and its Surroundings



distance from the main road (up to thirty minutes on foot). This guaranteed comparability of our measurements of trade-offs between multiple forest outcomes at the community scale. Household representatives provided information about their productive activities, surface of forest clearances, number of cattle, use of non-timber forest products, and general sociological characteristics. Average household mobility for each community was calculated based on the average number of villages in which households spent a maximum of two weeks in the year prior to their interview.

We defined households' incomes as the aggregate of cash and consumption values that a household derives from its various farm and off-farm activities. Estimates of the levels and the relative proportions of incomes from the different household activities were established using a methodology based on two modules:

1. *Picture weighting to record farmers' perception of income proportions*: household representatives were presented with a number of pictures showing main sources of household income, and were asked to distribute twenty-five tokens among these pictures according to the relative importance of these sources of income in their household's economy — the greater the importance, the more tokens (Angelsen et al., 2011). Based on these weightings of sources of income per household, the proportion of each income category was then calculated for each of the two groups — indigenous Tsimane' and Andean settlers — for the purpose of comparison.
2. *Parcel mapping and agricultural income survey*: farmers were asked to draw a map of their parcels, showing the location of each specific single crop and combination of mixed crops and indicating the corresponding cropping periods, surfaces covered, yields and proportions sold on the market. Farmers were also asked what proportions of the land they had cleared had previously been old-growth forest and fallow land, respectively. The focus in this study was on the surface cleared in 2010, looking back on the one-and-a-half years preceding the survey. In 20 per cent of the cases, we visited the parcels to observe the crops and asked more specific questions about agricultural techniques, cropping calendars and uses of products.

Institutional analysis was based on focus groups and qualitative interviews. Researchers spent two to three weeks in each community. During this time, they carried out a cycle of at least three focus groups, held in the evening with all of the community's elders — both men and women — to obtain information about the settlement's history, community organization, relationships with external state and non-state organizations in the area, conflicts over resource appropriation, rules, and possible sanctions. To complement focus groups, we also carried out semi-structured individual interviews. All relevant information from focus groups and interviews was entered in a semi-open survey form based on researchers' field notes, to enable systematic comparison between indigenous Tsimane' and Andean settlers.

For the purpose of this study, we defined old-growth forest as a dense forested area that had not been cleared in the previous twenty-five years. To complement our knowledge about old-growth forest we also assessed the number of different tree species, as well as forest biomass per hectare. Interest in old-growth forest is justified by its extremely high vulnerability

to land clearing, and because it is specifically targeted by carbon capture and conservation programmes. Land cover was mapped using Landsat images taken in three different years.² For visualization purposes, several colour composite images were first created for each year.³ In addition, a principal component analysis (PCA) was performed on six bands (1 to 5 and 7). To improve the precision of the old-growth forest/non-forest map in selected areas, data were digitalized manually.⁴ The result was checked against SPOT images available for some areas and compared with a sample of field observations representing each class of forest and non-forest for the 2011 image. Old-growth forest areas were then calculated for a time series covering the years 2001, 2006 and 2011. By subtracting the total forest area in 2006 from that in 2001, and that in 2011 from that in 2006, we deduced deforestation during the two five-year periods of 2001–6 and 2006–11.

Old-growth forest species diversity and biomass were assessed by sampling a total of 320 forest plots (thirty to ninety in each village depending on forest size, resulting in a sampling error of no more than 10 per cent). Plot locations were determined using the random function in the ArcMap GIS software. Each plot consisted of three concentric circles. Within a radius of 10 m, we sampled all individual plants with a diameter at breast height (DBH) greater than 10 cm (upper-stem and mature trees); within a radius of 3 m, we registered all individual plants with a DBH of 3–10 cm (saplings); and within a radius of 0.5 m we recorded all natural regeneration and individual herbaceous plants. Forest sampling was carried out in direct collaboration with hired villagers. The resulting empirical data were used to calculate species diversity (H') using the Shannon-Wiener index (Önal, 1997). Above-ground biomass and carbon were calculated using Brown's methodology (Brown, 1997). Finally, we also calculated the opportunity cost of reducing CO₂ emission from agriculture for each settlement, using the methodology developed by Pagiola (2009) and taking the complete 2010 farming seasons as a reference.

RESULTS

History of Settlements

The Pilon Lajas Biosphere Reserve and Indigenous Territory (PLR) was created in 1992 by presidential decree. This happened in response to years of persistent demands and struggles by indigenous Tsimane' and Mosetene

2. TM and ETM+ sensors, spatial resolution: 30 m, reference coordinates: WRS-2 Path = 001/Row = 070. Two Landsat7 ETM+ images dated 2001–06–29 and 2006–08–23, one Landsat5 TM image dated 2011–11–08.

3. Red-Green-Blue combinations of TM/ETM+ bands 4–5–3, 7–4–3, and 3–2–1.

4. This detailed visual interpretation was possible because the surface covered was fairly limited (i.e., equivalent to less than 500 × 500 pixels).

groups for access to land and natural resources. In 1997, their right to the land was additionally recognized in a land title granting them common property rights and declaring the land as non-mortgageable and non-divisible. The Tsimane' group originated mainly from the neighbouring municipal territories of San Borja along the Maniqui river. They have been accessing the PLR area since time immemorial for hunting and fishing. Tsimane' populations follow a pattern of intense movement, which means that groups leave their communities of origin for periods ranging from several weeks, or a season, to multiple years. This high level of mobility is a cultural characteristic that allows them to gather natural resources and transmit techniques, knowledge and agricultural practices and resources across a fairly vast territory. The movement patterns depend on complex mechanisms of socialization and on changes in resource availability over time (Ellis, 1996).

Andean indigenous people have settled in the eastern part of the PLR. Their settlement began with the launch of a large government project in 1974,⁵ in the course of which the National Institute of Colonization distributed land to settlers. The units of land distributed were called *colonias*; each *colonia* was composed of approximately forty parcels of 25 hectares per family, amounting to a total surface of 1,000 to 1,500 hectares including a common parcel. The first migrants arrived in the middle of the 1980s, mostly from the Andean city of Potosí, where the collapse of the mining industry had left many people unemployed. Each settlement has a population of around 50 to 100 individuals. Some households own more than one parcel and share the land between several family members. Around 80 per cent of the settlers still belong to the first migrant generation. Only a few houses are located on the cultivated parcels, as 95 per cent of the families have their main residence in the village of El Palmar. The relationship between Tsimane' and Andean settlers is generally collaborative; occasional conflicts are mainly over land and resource appropriation. These conflicts have diminished considerably since the land registration process in 2003, during which both groups were granted formal land titles.

Main Institutions and Governance Process

Local communities are struggling to find appropriate arrangements that entail acceptable trade-offs between forest benefits, institutional transaction costs and forest sustainability. The main and formally elected authority of the Tsimane' is the *corregidor*, whose main function is conflict regulation. In two of the three Tsimane' communities studied, power — expressed, for example, in the authority to regulate access to timber — has been concentrated in the hands of a few individuals who mainly belong to the same family and who generate more income from timber extraction than the rest of the community.

5. Supreme Decree No 11565 of 27 July 1973.

Since the local elite has failed to define clear rules for timber extraction, conflicts between community members over access to forest resources are frequent. The third Tsimane' community decided to clarify their forest rules and make sure the rules conform with national forestry law. To this end, the community adopted a formal forest management plan and delegated its implementation to a local (non-indigenous) enterprise. This has resulted in permanent conflict between the community and the forest enterprise because benefits for community members have dropped to unacceptably low levels.

The three Tsimane' communities studied are part of a larger set of twenty-one communities whose representatives elect a regional authority called the Consejo Regional Tsimane' Moseten' (CRTM). The CRTM represents the Tsimane' and Mosetene communities of the PLR in regional political processes; however, it has no control over local forest management and extraction. Local communities and the CRTM depend heavily on the Biosphere Reserve Authority (BRA), which is composed of a director and a management committee appointed by the National Service of Protected Areas (SERNAP). The relationship between the BRA and the indigenous communities is characterized by permanent conflict, mainly over infringements of national rules — to be enforced by the BRA — that forbid timber extraction. So far, the BRA has not succeeded in stopping timber extraction in the protected area and its buffer zone.

In the Andean migrant settlements, the main institution is the *sindicato* (Spanish for labour union). The *sindicato* is composed of the parcel owners (mainly men) and their families. An executive board is elected every year at an annual assembly. Board members assume certain duties (*cargos*) consisting of administrative responsibilities that are renewed on the basis of annual rotation. The executive board manages a larger common parcel situated at the centre of the *sindicato*'s territory. This provides the board with the resources required for its functioning. Part of the common parcel can also be rented to *sindicato* members for commercial purposes or to temporarily help farmers lacking land. Many communities have placed a small part of the common forestland under protection, mainly to ensure members' access to forest biodiversity in the form of medicinal plants and other non-timber forest products (NTFPs). Families work their parcels individually, but are required to participate in certain collective tasks, such as road maintenance, and to pay regular taxes, which are used to cover the financial expenses of the *sindicato*. The *sindicato* can seize the land of an uncooperative member and sell it to another member. All resources contained in an individual parcel belong to the owner and are not subject to any restrictions on use or extraction by the *sindicato*. The main conditions owners must fulfil in order to keep their parcel are to work it, be present at meetings, pay taxes, and perform the rotating duties of the community organization. Each local *sindicato* is part of a broader organization called the Federation of Agroecological Producers of Yucumo (FEPAY), which is the Andean settlers' main political organization at the provincial level. Despite its name, FEPAY is more involved

Table 1. General Characteristics of Communities Studied

	Tsimane'				Settlers			
	Alto Colorado	Santa Rosita	Bajo Colorado	Mean	El Bala	Nueva Belén	Villa Imperial	Mean
Year of founding	1950	1964	1970	1961	1987	1990	1983	1987
Population	167	68	133	122.7	87	47	152	95.3
Number of households	27	17	22	22.0	17	16	29	20.7
Pop. density (fam./ha)	0.028	0.025	0.262	0.1	0.036	0.033	0.103	0.1
Mobility ^a	33	36	36	35.0	21	23	47	30.3
Education ^b	7.9	7.1	5.6	6.9	9.4	9.8	12.8	10.7

Notes: a) Mobility is the average number of villages in which community households spent a maximum of two weeks in the year prior to their interview

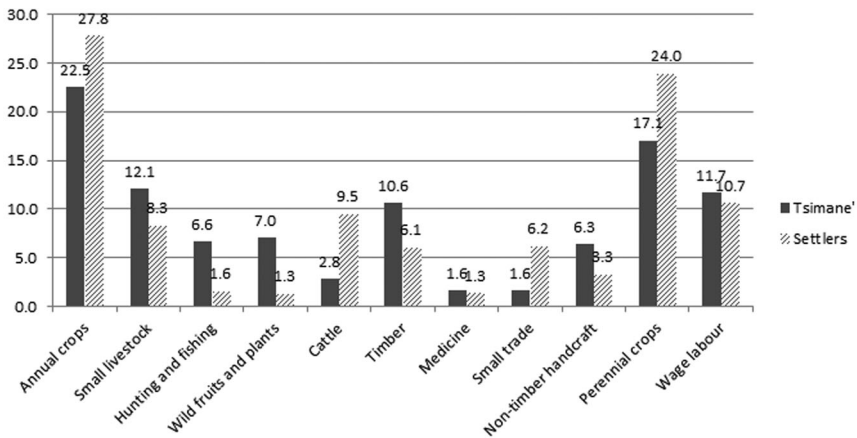
b) Education is the average number of years of schooling per individual

in supporting agriculture production than sustainable forestry. In the past decades, FEPAY played an important role in advocating formal recognition of settlers' property rights through a process of land registration. Table 1 presents some general characteristics of the communities studied.

Productive Strategies, Land Use and Household Incomes

In Tsimane' communities, the generalized collective appropriation of land allows for great agricultural flexibility and fosters crop rotation. Household heads must obtain permission from the *corregidor* to establish their cultivation areas. Agricultural production is based on a rotation of rice, maize, cassava and plantain. The forest area cleared in 2010 for agriculture ranges from 1 to 2 ha per family. Small surpluses of agricultural products are sold on local markets. Cooperation between families is uncommon when it comes to agriculture. Cattle breeding is a marginal activity for Tsimane' families (3 per cent of household income). During fieldwork in the three Tsimane' communities we counted a total of forty-seven cattle; these were distributed among only 5 per cent of the families, with each family owning between one and thirty animals. Meat consumption and trade is based on hunting and fishing, which, however, account for only 7 per cent of household incomes on average (see Figure 2). Hunted game is divided between family members, and part of the product is dried for storage. Plant use for medicine and nutrition is also important: one study showed that Tsimane' communities based along the Maniqui River used 114 different plants for medicinal purposes. This knowledge also has a high potential for commercialization (Reyes-García et al., 2006). Extraction practices are regulated by multiple rules based on the Tsimane' cosmology, according to which non-human entities such as animals and spirits control the use of renewable resources (Daillant, 1998; 2003). In the communities visited, all families extract non-timber products, especially 'jatata' (*Geonoma diversa*), which is used to build roofs and is

Figure 2. *Perceived Importance of Agriculture, Forestry and Other Activities to Household Income (in per cent of total household incomes)*



sold on the local market. Handcrafted non-timber forest products account for about 6 per cent of household incomes. Mobility for fishing, hunting and gathering NTFP is also quite important and can last several weeks during different periods of the year. These extractive activities are based on kinship rules and reflect several fundamental aspects of socio-cultural reproduction (Castillo, 1988). Internal community rules define extraction sites and the distribution of resources for each family or clan. Families considered as 'permanent' residents of the community are authorized to extract resources by the main authority, the *corregidor*. Hunting and fishing have declined in the nearby areas due to the damage caused by the forest companies over the last twenty years, but are now growing in the more remote core area of the reserve (WCS, 2005).

Except for cattle breeding and cultivation of permanent crops, the Andean settlers' agricultural practices are similar to those of the Tsimane'. The forest area cleared in 2010 for agriculture ranges between 1.5 and 2 ha per family, and crops include cassava, rice and/or corn. Annual crops contribute 27.8 per cent of settlers' total household income, which is clearly a higher proportion than in the case of the Tsimane', who generate only 22.5 per cent of their income from agriculture. Perennial crops (plantain, citrus and cacao) are likewise important sources of revenue (24 per cent of household incomes). Households practise hunting and fishing only as occasional or leisure activities; these account for only 1.6 per cent of total household income. Forest fruits (NTFP) from individual parcels or common land contribute even less, at 1.3 per cent. Both categories are clearly more important to Tsimane' households, contributing 6.6 and 7 per cent, respectively, to their total income.

Since the beginning of the 1990s, settlers have received credits from small financial agencies, bypassing national legal restrictions on small properties.⁶ Credits are only partially invested in agriculture, as the example of Villa Imperial illustrates.⁷ Of a total credit sum that thirty-five families received during the five years preceding the survey (US\$ 12,250), 53 per cent was invested in off-farm activities such as commerce and transportation. Almost all settler families have at least one adult member mainly engaged in non-agricultural activities (woodwork, wage labour, trade, local transport). Most settler families employ landless migrants or local indigenous people as wage labourers (mainly for forest clearing and harvesting) in order to reduce the time they themselves spend on agriculture and to increase their involvement in off-farm activities.

Family savings and another 40 per cent of the credits received were invested in cattle. At the time of our investigation (2011), Andean settlers in the three communities owned a total of 310 cattle. The distribution of cattle among the families was not uniform: only 5 per cent of the households owned thirty to fifty-five cattle (standard deviation: eleven), and 25 per cent owned less than thirty cattle. In fact, breeding is not considered a highly profitable activity, especially on small parcels up to 25 ha; it represents a form of financial insurance rather than a regular monetary income (2.8 per cent of household perceived income for indigenous people and 9.5 per cent for Andean settlers). Despite the small number of large-scale cattle owners, most land conversion is from forest to pasture, especially in settlers' areas. The reason lies in the widespread practice of renting land to large-scale cattle owners, regardless of whether they are a member of the same *sindicato*. Indeed, a local parcel-renting market is currently emerging based on the property rights of landowners. This practice is contributing to soil compaction and massive conversion of forest to pasture.

Carbon Emission, Biomass and Species Diversity

Table 2 shows that the different production strategies are having distinct impacts on CO₂ emission, biomass reduction and species diversity. CO₂ emissions are much higher for Andean settlers' communities than for the Tsimane' communities. The two main reasons for this are that the settlers' productive system is clearly more oriented towards agriculture and cattle production, and that the Tsimane' are considerably more involved in forest extraction. In the period 2001–6, the settlers deforested more than twice the

6. According to national law, a small property is indivisible and a family patrimony; it cannot be mortgaged (Art. 41 par. 2, INRA Law No. 1715 of 1996). But since the *sindicato* offers a refunding guarantee, several financial agencies are willing to issue loans. In case of non-reimbursement, the *sindicato* withdraws the title from the individual owner and sells it directly to someone else.

7. Villa Imperial is the only community that agreed to share information about this critical aspect.

Table 2. Forest Characteristics in Tsimane' and Settlers' Communities

	Tsimane'				Settlers			
	Santa Rosita	Alto Colorado	Bajo Colorado	Mean	Nueva Belem	Villa Imperial	El Bala	Mean
Total surface (ha)	2,723	6,032	508	3,088	1,443	1,465	2,389	1,766
Old-growth forest (ha)	2,070	5,563	250	2,628	1,193	699	1,983	1,291
Net deforestation, 2001–2006 (in per cent of forested area)	3.6	4.0	27.0	5.1	12.3	29.9	7.5	13.9
Net deforestation, 2006–2011 (in per cent of forested area)	7.3	2.3	22.8	4.5	10.7	8.7	7.9	9.0
Number of species in old-growth forest	123	130	120	124	132	113	129	125
Species diversity H' in old-growth forest	3.5	3.5	3.5	3.5	3.6	3.5	3.6	3.6
Above-ground biomass (tons/ha)	259	260	259	259	568	389	340	432
Total carbon in secondary forest (tons/ha)	130	130	129	130	284	194	170	216
Carbon stock (tons)	268,329	723,569	32,428	341,442	338,689	135,832	336,986	270,502
Average annual CO ₂ emission,* 2001–2006	2,152	6,165	3,107	3,808	10,619	12,677	5,948	9,748
Average annual CO ₂ emission, 2006–2011	4,253	3,460	1,916	3,209	8,120	2,605	5,812	5,513

Note: * Calculated on the basis of net deforestation and carbon density in each community

area deforested by the Tsimane'. In the period 2006–11, deforestation among settlers decreased considerably compared to the previous five-year period. According to our interviewees, this is due to a reduction in the available area for forest clearing, which forced settlers to intensify their production. The high carbon stocks in Tsimane' forests can be explained by the fact that indigenous groups own larger areas of common land than settler groups.

Unlike overall carbon stocks, biomass per hectare is much lower in Tsimane' forests (259 tons/ha) than in Andean settlers' forests (432 tons/ha). This can be explained by the higher degree of degradation in Tsimane' forests due to their extractive practices. In recent decades, indigenous Tsimane' societies have undergone major changes due to contact with external agents from the logging sector, market inclusion, and the increasing proximity of urban centres (Bottazzi, 2008; 2009; Godoy, 2001). At present, most Tsimane' families are heavily involved in forest extraction to meet their financial needs. Logging accounts for 10.6 per cent of their monetary income, and they

Table 3. Opportunity Cost of Reducing Carbon Emissions from Tsimane' and Settlers' Agriculture

	Tsimane'				Settlers			
	Santa Rosita	Alto Colorado	Bajo Colorado	Mean	El Bala	Villa Imperial	Nueva Belén	Mean
Area cleared in 2010 for new crops (ha)	21	36	52	37	28	35	28	30
Net present value (NPV) of agriculture (US\$/ha)	505	567	446	506	491	730	344	522
Opportunity cost (US\$/tCO ₂)	1.62	1.70	1.44	1.59	2.56	2.88	1.01	2.15
Proportion of crops grown on previously fallow land (% of land cleared in 2010)	47	40	48	45	95	83	79	86

extract 500–1,000 m² of timber annually. At 6.1 per cent, logging generates a considerably smaller portion of Andean settlers' income. Nonetheless, this difference in extractive practices has only a slight impact on species diversity, which differs by only 0.1 H'. This is because the timber market concentrates on very few highly valuable species, including mahogany (*Swietenia macrophylla*), cedar (*Cedrela* spp.) and *Amburana cearensis*.

Opportunity Cost of Reducing Carbon Emissions

Data presented so far show that Tsimane' and Andean settlers' different institutional forms of natural resource appropriation result in different patterns of household income composition, with varying effects on carbon emissions, but not so much on tree species diversity. This means that the manifold site-specific trade-offs between agriculture and forestry influence the opportunity costs of human activity in several ways. The opportunity cost of reducing carbon emissions from agriculture and cattle production in 2010 amounted to US\$ 1.59/tCO₂ for the Tsimane' and US\$ 2.15/tCO₂ for the Andean settlers (see Table 3).⁸ The main reasons for this difference are: (1) Tsimane' cultivation techniques produce lower yields compared to settlers' agricultural practices; (2) Tsimane' produce less cattle than the settlers; and (3) Tsimane' clear a larger proportion of dense old-growth forest than the settlers to establish new fields, which is more labour-intensive than

8. In 2011, the non-governmental organization Conservation International assessed opportunity costs in a closed area including some of the communities that are part of our case study, and found that 80 per cent of forest conversion, including for large-scale cattle ranching, corresponded to an average opportunity cost of US\$ 2.01 per ton of CO₂.

clearing fallow land (in 2010, 55 per cent of the forest area cleared by the Tsimane' was in old-growth forests, releasing about 130 tons of CO₂ per ha). The Andean settlers' farming system generates higher annual opportunity costs of reducing carbon emissions because a large proportion of the annually cleared areas is on land that has been fallow for five to eleven years and hence has a lower carbon density (in 2010, 86 per cent of the forest area cleared was on fallow land, releasing about 59 tons of CO₂ per ha). In addition, Andean settlers use farming techniques (e.g. fertilizer application) that generate higher yields, and earn more income from cattle breeding or pasture renting. The disappearance of primary and old-growth forest on the settlers' land forces them to intensify production, for example through more intense soil management and long-term investment in permanent crops.

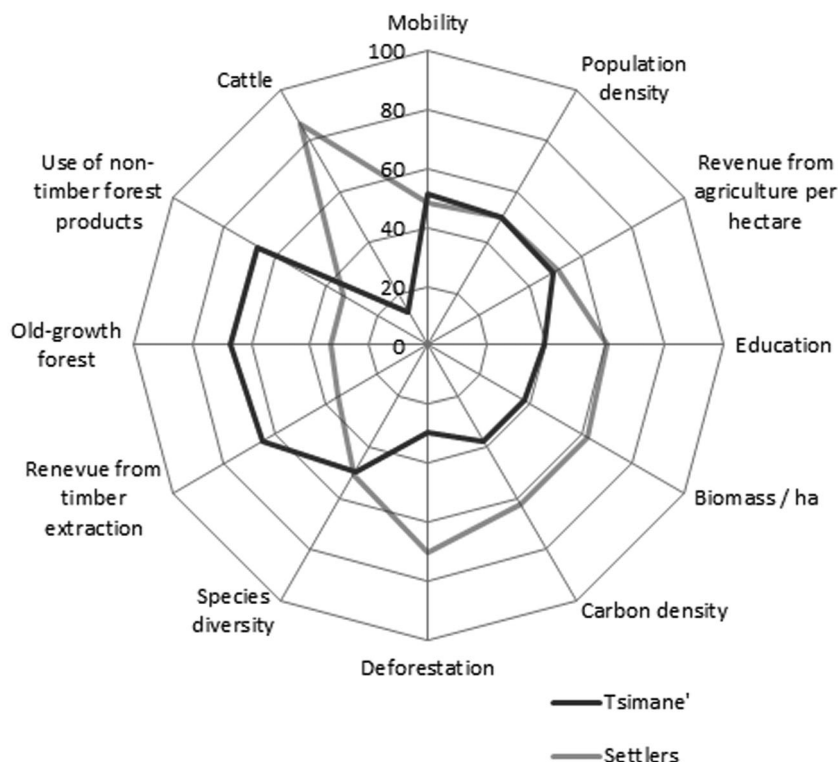
DISCUSSION

Our empirical comparison between Tsimane' and Andean settlers is an attempt to shed light on how different socio-institutional characteristics influence trade-offs between multiple forest-related outcomes in the same ecological context (Figure 3). Based on the main trade-offs targeted by carbon sequestration and conservation programmes, we focused in particular on local drivers of sustainability, property rights systems, local enforcement and governance processes. This section will look at each of these in turn.

Understanding Local Drivers of Sustainability

Tsimane' ecological knowledge allows a variety of collecting practices and reduces risks of market dependencies and monoculture. Human mobility makes individuals circulate in accordance with resource mobility and availability over time, and allows them to share knowledge and cultural practices about forest multiple incomes with other members of their community. Small-scale shifting cultivation and collective (rather than individual) use of pasture areas are flexible forms of land use that allow time and space for forest regrowth. The relatively low market integration of the Tsimane' leads them to maintain subsistence cultures and diversify both their food consumption and their sources of income by harvesting non-timber forest products. The result is a high degree of win-win synergies between household incomes and forest cover. However, external socio-environmental changes along the Pilón Lajas buffer zone frontier are deeply influencing Tsimane' society: loss of hunting resources, acceleration of land cover change from forest to pasture in adjacent areas, loss of relevant ecological knowledge, and changes in consumption patterns are among the processes leading to fundamental behavioural transformations in Tsimane' societies (Reyes-García et al., 2007).

Figure 3. Trade-offs and Synergies between Livelihoods, Species Diversity Conservation and Carbon Sequestration in Indigenous Tsimane' and Andean Settlers' Communities



Note: The index is constructed as the sum of the mean values for Tsimane' and Andean settlers, respectively, for each indicator category described in the results part. For the purpose of comparison, we represented the share of each group on a 100 per cent scale.

For the Andean migrants, the situation is quite different. Their productive system is oriented towards more short-term yield with lower labour investment and a low diversification of NTFP extraction. Agricultural production is coupled with growing investments in off-farm activities, resulting in stronger market and monetary integration. The settlers' focus on cattle breeding makes land a resource per se, which is used as a kind of financial insurance for times of hardship and extraordinary events such as health problems or social obligations. Once land is converted to pasture, it becomes difficult to relaunch agricultural production, especially since there are still no technical means for tillage (Mattos and Uhl, 1994). Thus, some individual parcels have become 'stored resources' for medium-term financial investment with minimal labour input. This has considerable negative consequences in terms of deforestation and carbon emission.

In this context, where both societies depend heavily on agriculture, a strictly offset-based financial compensation for reducing activities would be risky. The dependence of beneficiaries on external or market funding in such compensated reduction schemes poses challenges with regard to permanency and food security; reasons for this include the current absence of sustainable and profitable alternatives to agriculture and forest extraction, as well as the importance of these activities in the overall context of economic and social practices in Tsimane' and Andean settlers' societies. Most assessments of the opportunity cost of carbon sequestration are based on the speculative assumption that in the absence of agricultural activity, farmers will automatically find a substitute activity in a closed area that will compensate them for the work on their parcel (Bellassen and Gitz, 2008; Grieg-Gran, 2006; Pagiola, 2009). Our research determined an average opportunity cost of US\$ 1.87 per ton of CO₂ emission from agriculture across both groups. While this net value is probably lower than the carbon market price, it does not include the value of labour that farmers recover by selling their products on the local market. In the absence of profitable economic alternatives that could absorb labour in the area, the payment of opportunity costs based on net benefit (excluding labour input) would not suffice to compensate the full opportunity cost of farmers' current agricultural activities. Besides, the dependence of other economic sectors on agriculture (e.g. food trade, wage labour input, transport, etc.) means that these sectors might also be affected by a reduction in food production. Carbon sequestration payments based on the principle of compensated reduction of agricultural activities would therefore affect local livelihoods both directly and indirectly. Moreover, a radical change in carbon prices or the discontinuation of payments by donors would have harmful effects on local communities if they relied exclusively on the carbon market.

REDD+ eligibility requirements can also lead to inequalities between groups that are not eligible in the same way for PES. The principle of 'additionality' requires that a REDD+ project must demonstrate real, measurable and long-term benefits in terms of reduced carbon emissions compared to so-called business as usual.⁹ Different scenarios (national versus local baseline or stock-based versus emissions-based approaches¹⁰) produce different levels of compensation for different forest user groups (Angelsen, 2008). For Andean settlers, an emissions-based approach would be much more profitable than a stock-based approach, considering that their emissions have been higher than those of indigenous groups in recent decades. For the

9. Business as usual is a policy-neutral reference scenario for future emissions; that is, projections of future emission levels in the absence of any policy changes or REDD activities (Angelsen, 2008: 136).

10. The emissions-based (or flow-based) approach measures and credits only the net changes in carbon stocks over time (emissions). The stock-based approach makes payments a function of the total carbon stock in the forest at any one time (i.e., absolute levels, and not changes) (Angelsen, 2008: 17)

Tsimane', by contrast, the emission-based approach would not be profitable at all, as they have cleared less forest and their carbon stocks are still considerable. This means that using the same baseline would simply lead to greater inequalities¹¹ and could encourage the less advantaged groups to 'protest' by increasing illegal extraction. A basic understanding of local settlement history and current productive strategies is indispensable for defining an appropriate mechanism. This, in turn, can only be achieved based on medium- to long-term cooperation between the multiple stakeholders involved in a REDD+ project with the aim of jointly implementing concrete inputs (institutional or technical) rather than mere remote-sensing based monitoring of emission reduction.

Accordingly, REDD+ implementation should be based mainly on supporting local initiatives leading to concrete improvement of existing alternatives, such as sustainable intensification of mixed systems (Herrero et al., 2009). As we observed, recent pressure on old-growth forest areas has induced a change in settlers' perception of their productive systems' economic sustainability. Between 2005 and 2011, a growing number of households started to invest in medium- to long-term agroforestry systems, planting perennial crops (e.g. citrus and cocoa) or managing soil quality by growing mixed crops and nitrogen-fixing plants during managed fallows (e.g. by cultivating kudzu (*Pueraria phaseoloides*) or kanaulali (*Canavalia ensiformis*)) — measures that are expected to result in higher yields after three to five years. These experiences mean that reduction of CO₂ emissions by deforestation of the whole agroforestry system can be compensated by implementing different and more intensive agricultural production systems. As demonstrated in similar contexts, if such agroforestry systems are accompanied by cash crop or subsistence crop agriculture based on a rotation of annual and perennial crops followed by a fallow period of five to eleven years, the system could achieve acceptable viability over time (Leakey and Tchoundjeu, 2001; Smith and Scherr, 2003; Soto-Pinto et al., 2010; Ticktin et al., 2003). However, our interviews indicate that for poor Tsimane' and Andean settlers' households, investment in longer-term agroforestry systems still means a considerable shortage of income in the short term, which many of them cannot afford, even though it has been demonstrated that these systems produce profitable and sustainable yields in the long run (Milz, 2010). This explains why farmers in the area hesitate to make such investments. Nonetheless, an adequately framed REDD+ project, embedded in settlers' and indigenous people's current practices and experiences and based on their willingness to be part of such an experience, would be more effective than a

11. Such differences among users also require a better understanding of physical carbon emission mechanisms (degradation versus deforestation, forest fallow versus old-growth forest). Applying the UNFCCC Tier1 monitoring standard, for example, would mean focusing exclusively on deforestation, while completely disregarding the type of degradation caused by the Tsimane'.

strict top-down monetary scheme of compensated reduction. However, such collaboration based on external funding would require adequate property rights and institutional arrangements.

Flexible Property Rights and Strong Local Enforcement

Securing property rights, individual or collective, is not a sufficient measure to improve effectiveness of REDD+ implementation (Palmer, 2011). Local institutions need to have a strong enforcement capacity and environmental norms have to be implemented in order to improve the sustainability of social-ecological systems (Chhatre and Agrawal, 2008). As we saw in our case study, property rights have a strong influence on productive strategies. They can have positive effects — such as encouraging innovation and intensification of agricultural production or a shift from annual to perennial crops — as well as various ‘perverse’ effects resulting in deforestation or forest degradation. Comparison between Tsimane’ and Andean settlers’ productive logics gives us a contrasting illustration of how institutional patterns influence socio-ecological processes. A PES or REDD+ intervention in such a differentiated context should strive for an equilibrium between the financial value of land, the population’s mobility, the opportunity cost for appropriators to move to another sector and, more importantly, actors’ institutional motivations to participate in a conservation process (Vatn, 2010).

A collective property system like that of the Tsimane’, which is characterized by highly flexible resource use (common pasture area, circulation of cultivated areas, use of a diversity of non-timber forest products), allows for greater compatibility between social and ecological systems. External exclusion is enforced to a considerable degree on collective land owned by indigenous people. Moreover, the indigenous collective owners do not have the option to sell, divide or mortgage their land. Thus, such land per se has almost no economic market value, which reduces the risk of market prices for land exceeding the value of productive practices. This is an advantage over the quasi-individual property system of the Andean settlers. However, the institutional potentials of Tsimane’ resource appropriation for preserving social-ecological systems suffer from a lack of local enforcement of rules. The Tsimane’ communities’ internal institutional arrangements are generally unclear and leave room for uncertainties about how resources are to be managed and distributed. These permanent uncertainties lead to specific forms of quasi-open access and favour elite capture of benefits, which in turn can lead to high levels of forest degradation. Implementation of REDD+ in such a context would certainly come at a lower cost per hectare (due to low opportunity costs and low carbon emissions), but it would involve higher transaction costs and higher risk of leakage due to low excludability and weak internal arrangements. In this case, REDD+ could have various effects: for example, it could create pressure to privatize land access

with a view to avoiding conflicts, or it could incentivize a process among stakeholders towards collective sustainable forest management.

In the Andean settlements, regardless of the quasi-private property regime, collective norms are abundant and individuals depend heavily on each other due to the power of their collectively governed local political bodies. Hence, although each parcel of land is clearly delineated, its alienation is conditioned by strong political control of the local *sindicato*. However, the high institutional capacity of Andean settlers has little positive impact on the sustainability of their agro-ecological system. On the contrary: the high level of deforestation in the settlements can be explained by a relationship between the land category, the robustness of political organization in the *sindicato*, and the productive system. For most settlers, private property is a way of producing short-term revenue on land without investing much in labour — by obtaining credit, converting the land to pasture, and investing into cattle as a financial saving strategy. The land can be sold anytime or rented to cattle owners thanks to the strong support of individual property rights offered by the local *sindicato* and the state. This clear individual division of land leads to lower transaction costs for managing resources, but the potential financial value of land and hence the opportunity cost of carbon sequestration relative to productive activities is higher as well (in the Andean settlements it was US\$ 0.65 higher per ton of CO₂ than in the Tsimane' settlements). In this context, a REDD+ compensated reduction mechanism would be more expensive for investors but would incur lower transaction costs. The robust local institutions would enable the local *sindicatos* to clearly identify and guide the participation of each landowner.

As the case study has shown, the effects of productive strategies on carbon emission do not follow a strict logic of pursuit of financial income. They are also shaped by land users' strategies to achieve 'resource security' (Cotula and Mayers, 2009). Accordingly, REDD+ implementation in the context of this type of property system could not be based strictly on compensating opportunity cost of production, but would require a process of further entitlement (Leach et al., 1999) — especially in the case of indigenous people, who have received access rights to land but still lack full extractive or use rights to forest resources (Asquith et al., 2002; Bottazzi, 2009; Doherty and Schroeder, 2011). Indeed, this is the reason why they are caught in a quasi-open access situation. In our understanding, an adequate institutional arrangement would have to strike a balance between users' need to secure land and the enforcement of societal control over the ecological effects of the various land uses.

More recent trends in Bolivia are actually moving towards promoting the establishment of intermediate forms of tenure that allow better articulation of individual and collective land rights. We think that this option would be favourable for REDD+ implementation and, more generally, for sustainable forest use. Such new land categories would be formalized at the communal level under a single collective title, but the local authority would then have the authority to distribute the land to individuals according to the

community's own governance principles. The resulting land and resource distribution could then be formalized again by the government authorities or left open, depending on the community's needs. Such arrangements have already been implemented in certain areas in the highlands; in the lowlands, however, the idea is met with strong resistance by some factions who fear territorial loss and fragmentation (Chumacero et al., 2009; Urioste et al., 2007). Recognition of communal authorities by the national government and the municipality has also been advocated by institutional theorists, who argue in favour of legitimizing communal self-organization and promoting adapted arrangements that allow for spatial divisions based on local communities' own criteria (Ostrom, 2000). This would provide a basis for enforcing the liability of forest user groups without completely compromising the specificity of socio-ecological patterns in the societies involved.

REDD+ in an Adaptive and Multi-level Governance Process

Differences among local governance structures call for adapting the mechanisms of the REDD+ programme to each individual situation, taking into consideration the coherence of national policy frameworks and trying to avoid contradictory legislation or laws (Hall, 2008). Success of REDD+ implementation depends on the existence of a decentralized self-organized governance system (Hayes and Persha, 2010; Wunder and Albán, 2008). Our comparative case study has shown how historical processes and socio-cultural characteristics can produce contrasting institutional configurations at the local level in areas that are geographically close to each other. In the case of the Tsimane', the relative change from sustainable to unsustainable forest use is facilitated by a lack of regulation at the local level and by the weak governance capacity of local and regional indigenous organizations. Conversely, Andean settlers have strong local and regional governance structures, but have become widely involved in an emerging land market. By investing in cattle breeding, they are striving for short-term economic benefits while reducing labour inputs. Implementation of a PES programme such as REDD+ in such differentiated contexts would certainly require a lengthy process with high transaction costs, as it could not be achieved without specific institutional arrangements for each group. REDD+ institutional mechanisms cannot be determined by external agents but must be proposed in a process of regional and local consultation led by the indigenous people or by farmers themselves (Blom et al., 2010). This participatory process would ensure that each programme is embedded in the different population segments, thus avoiding the risk of benefit capture by local elites, as demonstrated in previous PES projects (Wunder et al., 2008).

Strong local enforcement requires a coherent national resource regime and an adaptive multi-level governance structure (Termeer et al., 2010). As we have seen, deforestation is not driven exclusively by the pursuit of

maximum short-term benefits, but also represents a way of securing property rights and access to credit. As has been shown in other Amazonian areas as well, this strategy has been a strong incentive for converting forest to pasture, especially because some legislation declares forest clearance a prerequisite for securing property rights (Angelsen, 1999). Indeed, local implementation of REDD+ should be accompanied by the amendment of complementary land and resource legislation to avoid fundamental contradictions between sustainability principles put forth by the REDD+ programme in the forestry sector and regulations regarding the use of other resources, such as water, land, soil nutrients, oil and gas, or even leisure activities like ecotourism.

More precisely, a reform of the entire forestry regime is urgently needed in Bolivia. During the neoliberal regime, most policies sought to increase peasant productivity in response to international demand for soya and beef from the Bolivian lowlands (Pacheco et al., 2010). Since the last forestry reform in 1996 there have been very few incentives to encourage sustainable community forestry. Despite some small amendments, the forestry law still favours large-scale forest enterprises based on the concession principle and encourages purely commercial timber extraction that ignores more comprehensive forms of forest use by local communities. A new forestry law should facilitate administrative procedures for local communities to have a management plan approved and self-implemented by their members. The new law should also allow for non-timber forest products regulation in order to facilitate access to these resources and their use, further processing, and distribution. The Morales government has retained the former forest policy principles, while reducing or even completely stopping monitoring activities in an effort to cut government expenditures and respond to demands for local self-determination (Redo et al., 2011). The main reforms undertaken since 2006 are concerned with land redistribution and have not addressed forestry issues (Bottazzi and Rist, 2012). Recent evaluations show that only 5 per cent of the potential for sustainable forest management has been realized in Bolivia, and that 50 per cent of all Bolivian timber is still extracted illegally (Pellegrini and Dasgupta, 2011).

CONCLUSION

In a recent letter addressed to the ‘indigenous brothers of the world’,¹² Bolivian President Evo Morales strongly condemned the ‘commodification of nature’ potentially represented by the REDD+ mechanism. His main criticism, shared by a number of scholars, is that such an international market mechanism to reduce forest carbon emissions would allow richer, mostly

12. Published on <http://pwccc.wordpress.com/2010/10/07/presidents-letter-to-the-indigenous-peoples-nature-forests-and-indigenous-peoples-are-not-for-sale/> (accessed on 20 December 2012).

industrialized countries to maintain high carbon emissions, while restricting poorer countries' development options and turning them into providers of cheap ecological services (Lohmann, 2009; 2011; McAfee, 2012). In that sense, transnational economic forces and international legislation, by imposing liberal measures on economically weaker countries, play a role that is frequently counterproductive, with harmful consequences for local agriculture, NTFPs and biodiversity (Amanor, 2012; Borrás et al., 2012). Nevertheless, a clear distinction has to be made between the origin of REDD+ funds (market, private or public donors) and the criteria for the distribution of PES/REDD+ funds to local communities; the present article focuses on the latter.

Our findings further justify warnings against uncritical promotion of REDD+ and PES. The case studies have shown that the most critical factors or risks related to REDD+ and PES are: (1) the potential reinforcement of economic inequalities due to different past and expected impacts of land uses on ecosystems (baseline) depending on the socio-cultural groups targeted; (2) pressure on land used for food production, potentially leading to a reduction in food security and pushing labour towards scarce off-farm income opportunities (Peskett et al., 2008); (3) increasing dependence on external funding and carbon market fluctuations rather than local productive strategies; and (4) creation of new incentives for land privatization and commodification to avoid transaction costs under collective property rights.

However, the potential risks of REDD+ and PES implementation should not automatically exclude the possibility of indigenous people and peasants in forested tropical areas potentially benefiting from such initiatives under certain conditions. To prevent 'perverse effects', REDD+ and PES mechanisms should be used to help improve the governance capacity of existing collective and quasi-private land and natural resource property rights while favouring input-based scenarios, such as sustainable soil and forest management. As shown in our study, local societies have already started to develop productive and institutional strategies aimed at reducing the negative effects of their various uses of land. So far, these strategies have remained weak in the Bolivian lowlands due to a lack of financial, institutional and technical support. Consequently, REDD+ should be oriented towards direct support of such local and regional initiatives rather than being limited to payments for 'reducing' agricultural production.

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